DEVELOPMENT OF THERMAL PROTECTION SYSTEM

FOR A

CRYOGENIC SPACECRAFT MODULE

Contract NAS 3-4199

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INTRODUCTION

This document is the nineteenth Monthly Progress Report on Contract NAS 3-4199, entitled "Development of Thermal Protection System for a Cryogenic Spacecraft Module," dated 30 June 1964. The reporting period covered is from 31 December 1965 through 31 January 1966. During this reporting period, the ground-hold test on the half-scale test module was completed. Preliminary data obtained during the test indicated that temperatures at the surface of the purge substrate were below the nitrogen liquification temperature. Hydrogen boil-off rates decreased with time from about 64 pounds per hour (just after completion of liquid hydrogen filling) to about 40 pounds per hour, after six hours.

To evaluate the basic performance of the insulation system under vacuum consideration, it was decided to run an orbital heat flux simulation test (as part of the LMSC Independent Development Program for Cryogenics) prior to performing the ascent mission test. The test was performed at the close of this reporting period. Preliminary data indicate that the equilibrium hydrogen boil-off rate was about 0.65 pound/hour. The data are presently being reduced and analyzed. The remaining series of vacuum chamber tests are planned to begin early in the next reporting period. The preliminary draft of the final report was begun. Draft sections of the Task I through Task IV inclusively are in preparation, and outlines for the remaining sections are being prepared.

INSULATION SYSTEM DESIGN (TASK I)

Insulation system design analysis planned for completion at this time under Task I has been reported previously in References 1, 2, and 3. Analysis of ground handling and transport problems for the full-scale system will be concluded subsequent to the half-scale test program.

STRUCTURAL SUPPORT DESIGN (TASK II)

Task II has been completed and reported in References 1 and 2.

COMPONENT SUBSCALE MODEL TESTS (TASK III)

Task III has been completed and results reported in References 2, 3, and 4.

HALF-SCALE SYSTEM MANUFACTURING (TASK IV)

Task IV has been completed and results reported in References 3, 4, 5, and 6.

HALF-SCALE TEST PROGRAM (TASK V)

The ground-hold test of the 82.6-inch-diameter tank test assembly was performed on January 7. The test tank was filled with liquid hydrogen. Insulation temperatures, shroud temperatures, and boil-off measurement data were taken for a period of approximately six hours. During this test period the insulation substrate was purged with gaseous helium at 30 SCFH, and the interstage volume between the tank and shroud was purged with dry gaseous nitrogen at 40 SCFH. Initially, the liquid hydrogen boil-off rate was approximately 64 pounds per hour (just after completion of liquid hydrogen filling). The boil-off decreased to approximately 40 pounds per hour after six hours. Preliminary test data indicated that some of the substrate purge bag temperatures were 20 degrees to 40 degrees lower than anticipated. This indicates the purge bag was at nitrogen liquification temperatures in some areas.

It was postulated that the cause of this may be an insufficient helium purge flow rate through the substrate. In order to help identify the problem area, a special helium purge test was performed and substrate air concentration data were taken. At one of the three locations checked, the major air concentrations were 50% with a flow rate of 30 SCFH, and 36% with a flow rate of 60 SCFH. Other locations in general were less than 5%. Final data processing through the computer was in progress at the close of the report period. It appears from preliminary information that all required data were obtained. Engineering analysis of these data will take place during the month of February.

Because of the temperatures on the purge substrate surface and the results of the special helium purge test, it was decided that an initial test under vacuum conditions and orbital heating be performed prior to performing the mission tests as described in the contract test plan. This test (being conducted as part of the 1966 LMSC Independent Development Program) will serve as a basis of comparison for the contract test and a basic performance point for LMSC's multi-layer blanket insulation system.

On January 26 the vacuum orbit test was started. The vacuum chamber was evacuated to 5×10^{-6} Torr. After this vacuum was achieved, the tank was filled with liquid hydrogen and the orbit heat flux program was established (shroud temperatures at 400°R).

Facility difficulties were encountered in controlling the tank ullage pressure at a constant level. This problem was eventually corrected and a constant ullage pressure of approximately 17.25 PSIA was established. During the test a problem with the control of two of the heat flux zones occurred. Since equilibrium conditions had not been obtained, the test was continued by manual control of the affected zones in order to maintain proper shroud temperatures. On Saturday, January 31, the test was terminated. The preliminary data indicated that equilibrium conditions had been achieved at the termination of the test. This preliminary test data indicated a boil-off flow rate of approximately 0.65 pound/hour. These raw test data were in the process of being computer reduced at the close of the report period.

The ascent mission test per contract test plan is planned to start early in February. Repair of the problem with the heat flux system was started at the close of this report period. The problem was identified as breakdown of the high voltage pass-through connectors into the vacuum chamber. These connectors are being replaced with a modified design.

FINAL DESIGN OF THERMAL PROTECTION SYSTEM (TASK VI)

During this report period the ground-hold test of the thermal protection system was completed. The data were put into the data reduction computer program and were properly quantized, but the plotting routine did not work. Consequently, the data have not yet been evaluated. It was found, however, that the temperature of the purge bag was below the nitrogen liquefaction temperature, but the explanation must await a complete study of the data.

Also during this report period, a space heating test was conducted under the Lockheed Independent Development Program to provide additional facility operating experience prior to the operational test planned for the thermal protection system. This would also provide a basis for evaluating any degradation due to the rapid pump-down in the planned test sequence. Although some problems were encountered, approximately seven hours of apparent steady-state data were obtained. This data have not been reduced and evaluated but the boiloff was approximately 0.6 pound per hour, which is 50% higher than the design value. Here too an explanation must await the plotting of all the data.

QUALITY ASSURANCE

During January liquid hydrogen tests on the complete tank system were initiated at Santa Cruz Test Base. The ground-hold test was conducted on 6 January 1966. Test Procedure LMSC 72383 dated 1-6-66 was used to perform the test. It had been intended to sample the insulation purge gas to verify the helium purge of the insulation fiberglas sublayer. However, the Gas Chromatograph was inoperative and it was not possible to verify that purge gas contamination was less than 1%. An attempt to use a 1/8-inch tube and the facility gas analysis system was unsuccessful. After discussion with representatives from Project, Test and Quality Assurance, it was decided to continue the test and to verify the helium purge condition of the insulation sublayer as a post-test verification.

The liquid hydrogen fill was accomplished on 7 January 1966. The test procedure was used with minor change during the liquid hydrogen fill. All 187 instrumentation channels apparently functioned as intended. Preliminary liquid hydrogen boiloff data between 40 and 60 pounds per hour were observed. Temperature data through the insulation system indicated temperatures of approximately 110°R at the sublayer purge bag. This is 40°R colder than anticipated. The computer output from the magnetic tape was excellent and accurate. Complete data are available and are now being reduced and analyzed.

The test procedure for the remaining tests was revised to provide for an earth orbit test before the ascent test. This test will provide comparison data for boiloff and temperatures before and after the rapid pumpdown ascent test. The

digital test data were reviewed and data tabulation sheets and graphs prepared to provide analysis of important test parameters during the remaining liquid hydrogen tests.

The facility cold wall, heat flux system, and vacuum chamber were assembled and functional tests and calibrations accomplished. Liquid hydrogen fill was performed on 26 January 1966. The chamber vacuum was maintained at approximately 5×10^{-6} Torr. However, it was not possible to control the test article ullage pressure to obtain steady-state boiloff data. Liquid hydrogen flow was measured through the 0-10 pounds per hour Brooks and through the 0-1.2 pounds per hour Rosemount systems.

On Friday, 28 January, a bypass was installed in the facility piping system to permit use of the Rosemount system for total flow measurement. However, as the test was resumed, two of twelve light banks in the heat flux failed to operate automatically. Manual operation of the heat flux system permitted continuation of the test. Continuous data were obtained for more than eight hours. Boiloff flow was between 0.6 and 0.7 pound per hour, ullage pressure 17.21 to 17.23 PSIA, and chamber vacuum at 4.8×10^{-6} Torr. The test sequence was terminated to permit repair of the heat flux system on 29 January.

It is anticipated that all liquid hydrogen tests will be completed during February. Preparation of the Quality Assurance section of the final report was initiated during January and should be completed during February.

REFERENCES

1. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. First Quarterly Progress Report for the period 30 June - 30 September 1964.

2. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. Second Quarterly Progress Report for the period 1 October - 31 December 1964.

3. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. Third Quarterly Progress Report for the period 1 January - 31 March 1965.

4. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. Fourth Quarterly Progress Report for the period 1 April - 30 June 1965.

5. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. Fifth Quarterly Progress Report for the period 1 July - 30 September 1965.

6. Development of Thermal Protection System for a Cryogenic Spacecraft Module - Contract NAS 3-4199. Sixth Quarterly Progress Report for the period 1 October - 31 December 1965.